WOODS HOLE OCEANOGRAPHIC INSTITUTION

REFERENCE NO. 67-3

OCEANOGRAPHIC AND UNDERWATER ACOUSTICS RESEARCH
CONDUCTED DURING THE PERIOD
1 MAY 1966 - 31 OCTOBER 1966

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Woods Hole, Massachusetts

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March 1967

PROGRESS REPORT

Submitted to the Undersea Warfare Branch, Office of Naval Research, under Contract Nonr-4029(00) NR 260-101.

Approved for Distribution Earl E Hays

Earl E. Hays, Chairman
Department of Geophysics

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ABSTRACT

This is a status report for the period 1 May 1966 to 31 October 1966 for Contract Nonr-4029 with the Office of Naval Research. Subjects of this contract are in Oceanic Acoustics, Physical Oceanography, Sea Floor Properties and Advisory Activities.

Preliminary results of a cruise by CHAIN to the Mediterranean and the Red Sea during the summer of 1966 are given. Sound-velocity and temperature structure south of Bermuda as observed from ATLANTIS II (June, July 1966) are described. Continuing analysis of acoustical and geophysical data is discussed. Papers, reports, and technical memoranda written during this period are listed.

INTRODUCTION

This report is a summary of the activities under Contract Nonr-4029 during the period 1 May 1966 to 31 October 1966 with the Woods Hole Oceanographic Institution. The major portion of this research has been carried out by members of the Department of Geophysics. In the middle of this period, Dr. J. B. Hersey resigned as chairman of the department to assume senior responsibilities in the Office of Naval Research and has been replaced by Dr. E. E. Hays.

The program under this contract is aimed at an understanding and prediction of the naval environment to enable the Navy to carry out its mission on a world-wide basis. This includes physical oceanography and sea floor studies, theoretical analysis and field work in acoustics and direct liaison with Fleet Units.

During this period CHAIN commenced a cruise to the Mediterranean and the Red Sea. Towed temperature sensors, bathymetry, continuous magnetic and gravimetric measurements, seismic profiling, sound velocity profiles, bottom photography, heat flow, coring and dredging were part of the program. During the Atlantic crossing, CHAIN participated in a planned NATO exercise (MILOC 66) in an area west of Ireland. The eastern Mediterranean received the major emphasis in geophysical studies, and the data obtained should add considerably to our knowledge of that area.

ATLANTIS II made a two-month cruise between Bermuda and the Antilles to continue the study of the sound velocity and temperature structure in that area.

Members of the department also conducted a cruise aboard CHAIN in May and June in the North Atlantic, Caribbean, and Gulf of Mexico to study and sample mid-water sound scatterers. This cruise was supported by the National Science Foundation.

Several short cruises were made to test equipment prior to longer cruises.

Analysis has continued ashore in sound transmission, bottom reflectivity, geological samples, seismic profile records, magnetic and gravimetric data. A rock magnetism laboratory has been established for studying more fully the physical properties of seafloor materials. Also, a micropaleontology laboratory has been set up to aid in the study of the sedimentary process. Development work has been done on a new hydrophone, on a device for measuring the reverberation from midwater sound scatterers, on towed temperature devices, and on a sound velocity package with corrected read out.

The addition of Drs. Edward L. Murphy and Eli J. Katz to the department has added strength in theoretical analysis. Dr. Murphy has been examining diffraction effects at turning points of rays, and Dr. Katz is looking at the causes of variability in long-range transmission.

Planning has commenced for a shallow water sound transmission study in the Baltic for June of 1967. This is in cooperation with several NATO countries. Important in its own right, we also can consider this a preliminary step in larger scale sound-transmission investigations.

PAPERS

The following papers were published during this period under Contract Nonr-4029 and related grants as noted:

Contribution No. 1418. Physeter Clicks, by R. H. Backus and W. E. Schevill. Whales, Dolphins and Porpoises, K. S. Norris, Ed., pp. 510-527, 1966. (Contracts NObsr-89464, NSF-G9579, GB543, and G6171).

Contribution No. 1433. Listening to Cetaceans, by W. A. Watkins, Whales, Dolphins and Porpoises, K. S. Norris, Ed., pp. 471-476, 1966. (Contract NObsr-89464).

Contribution No. 1545. Serpentinized Peridotite from the North Wall of the Puerto Rico Trench by C. O. Bowin, A. J. Nalwalk and J. B. Hersey. Bull. Geol. Soc. Am., Vol. 77, No. 3, pp. 257-270, 1966. (Contract Nonr-1367 and Nonr-4029).

Contribution No. 1649. Continuous Seismic Profiles of the Outer Ridge and Nares Basin North of Puerto Rico by E. T. Bunce and J. B. Hersey. Bull. Geol. Soc. Am., Vol. 77, pp. 803-812, 1966. (Contract Nonr-1367 and Nonr-4029; NSF Grant G-822)

Contribution No. 1671. An Earthquake Recorded at Sea by F. S. Birch. Bull. Seis. Soc. of Am., Vol. 56, No. 2, pp. 361-366, 1966. (Contract Nonr-4029)

Contribution No. 1678. Classification of Sea Floor Sediments with a Shipborne Acoustical System by L. R. Breslau, Le Petrole et La Mer Section I, No. 132, pp. 3-9, 1966. (Contract Nonr-4029, NObsr-72521 and NObsr-89464)

______ Classification of Natural Sounds in the Underwater Ambient by W. E. Schevill. U. S. Jour. Und. Acous., 16, 2, pp. 339-340, 1966. (Contract Nonr-4029)

Contribution No. 1787. Sound Structure and Directionality in Orcinus (killer whales) by W. E. Schevill and W. A. Watkins. Zoologica, 51, pp. 71-76, pl. I-VI. (Contracts Nonr-4446, Nonr-4029, and NSF GA-141)

Contribution No. 1853. Magnetic Survey over the mid Atlantic Ridge between 42°N and 46°N by Peter R. Vogt and Ned A. Ostense. Jour. Geophys. Res., 71 (18):4389-4411. (Contract Nonr-4029)

The following papers were submitted either under Contracts Nonr-4029 or Nonr-1367 and related contracts or grants as noted:

Contribution No. 1614. Seismic Reflection Profiles along the Line of JOIDES Drill Holes, JOIDES Drilling on the Continental Margin off Florida by K. O. Emery and E. F. K. Zarudzki. Submitted to U. S. Geological Survey - Professional paper. (Contract Nonr-4029 and NSF G-8358)

Contribution No. 1800. Seismic Reflection Observations on the Atlantic Continental Shelf, Slope and Rise Southeast of New England by Hartley Hoskins. Submitted to Journal of Geology. (Contracts Nonr-1367, Nonr-2866, Nonr-4029, and NSF GP-822, GP-1123)

Contribution No. 1802. Some Deep-Water Sound-Transmission Paths South of Cyprus, Part II, Diffraction Effects by Lincoln Baxter and Robert Brockhurst. Submitted to Jour. Acous. Soc. (Contracts Nonr-4029 and Nonr-4730)

Contribution No. 1828. The Geology of the Western Approaches of the English Channel V. The Continental Margin and Shelf under the South Celtic Sea by J. B. Hersey and W. F. Whittard. Submitted to Proceedings Volume of the International Upper Mantle Symposium. (Contracts Nonr-4029 and NSF GP2370 and GP822).

Contribution No. 1837. A Shipboard Oceanographic Data Processing and Control System by C. O. Bowin, R. Bernstein, E. Ungar, and J. R. Madigan. Submitted to IEEE Transactions of Geoscience Electronics. (Contracts Nonr-1367 and Nonr-4029) (Also WHOI Ref. No. 66-44)

Contribution No. 1855. Structure of the Western Somali Basin by E. T. Bunce, M. G. Langseth, R. L. Chase and M. Ewing. Submitted to Jour. Geophy. Res. (Contracts Nonr-4029, NSF GP-2370 and GA 283, also Lamont Geological Observatory Contracts Nonr266(48) and NSF G-22260)

Contribution No. 1388. Resonance Scattering of Sound by a Small Gas Bubble in Liquids by M. S. Steinberg. Submitted to Jour. Acous. Soc. of Am. (Contracts Nonr-1367 and Nonr-4029)

UNPUBLISHED WHOI REPORTS

The following unpublished reports have been completed during this period under Contract Nonr-4029 and other contracts or grants as noted:

WHOI Ref. No. 66-2. Track Charts, Bathymetry and Location of Observations, CHAIN Cruise No. 51, North Atlantic Ocean, Blake Plateau, Project Sea Spider, Part I, 22 July - 31 August 1965 by W. M. Dunkle and F. M. Dakin. (Contract Nonr-4029)

WHOI Ref. No. 66-6. Track Charts, Bathymetry and Location of Observations, and Cruise Journal, GOSNOLD No. 73, Geological and Geophysical Investigations in the Region of the Proposed Site for Project Sea Spider, 9 July - 6 August 1965 by A. J. Erickson and J. M. Woodside. (Contract Nonr-4029)

WHOI Ref. No. 66-7. Track Charts, Bathymetry and Location of Observations, CHAIN Cruise No. 55, North Atlantic Ocean, Caribbean Sea, 11 November - 19 December 1965 by J. E. Arena. (Contract Nonr-4029)

WHOI Ref. No. 66-13. Sound Velocity Measurements on the Blake Plateau by R. E. Payne. (Contract Nonr-4029)

WHOI Ref. No. 66-15. Track Charts, Bathymetry and Location of Observations, ATLANTIS II. Cruise No. 13, North Atlantic Ocean, 1 Sept. - 5 October 1964 by B. Cormack and W. M. Dunkle. (Contract Nonr-4029, Nonr-2196 and NSF GB-543 and GB-861)

WHOI Ref. No. 66-17. Radio Tagging of Whales by W. E. Schevill and W. A. Watkins. (Contract Nonr-4446)

WHOI Ref. No. 66-19. Index Charts to Cruises conducted by Members of Geophysics Department. Issue I, Sections I - XIV, Issue II, Sections XV - XXVIII, North Atlantic, South Atlantic and Indian Oceans, Mediterranean and Red Seas by W. M. Dunkle and H. C. Hays. (Contract Nonr-4029)

WHOI Ref. No. 66-20. Suggested Methods of Compiling and Indexing Scientific Observations for Cruise Navigation Reports by W. M. Dunkle. (Contract Nonr-4029)

WHOI Ref. No. 66-38. Track Charts, Bathymetry and Location of Observations, CHAIN Cruise No. 53, North Atlantic Ocean, Hatteras Abyssal Plain, 14 October - 27 October 1965 by J. C. Douglass and W. M. Dunkle. (Contract Nonr-4029)

WHOI Ref. No. 66-44. A Shipboard Oceanographic Data Processing and Control System by C. O. Bowin, R. Bernstein, E. Ungar and J. R. Madigan. (Contract Nonr-4029)

UNPUBLISHED TECHNICAL MEMORANDA

The following technical memorandum was completed during this period under Contract Nonr-4029(00):

WHOI Tech. Memo No. 3-66. Cruise Plans for ATLANTIS II, Cruise No. 22 by J. C. Beckerle. (Contract Nonr-4029 and Nonr-2866)

WHOI Tech. Memo No. 4-66. Instructions for the Use of the WHOI Capacitive Line-Hydrophone (The Snake) by S. T. Knott, F. R. Hess, R. T. Nowak and F. L. Lynch. (Contract Nonr-4029).

WHOI Tech. Memo No. 5-66. Outline of Cruise No. 61 of the R/V CHAIN to the Atlantic Ocean and the Mediterranean and Red Seas, July 9 - December 17, 1966 by E. F. K. Zarudzki. (Contract Nonr-4029)

WHOI Tech. Memo No. 6-66. Instructions for the Use of the Chesapeake Array as Reconstructed in June 1966 by S. T. Knott, R. T. Nowak, F. L. Lynch and F. R. Hess. (Contract Nonr-4029)

WHOI Tech. Memo No. 7-66. A Manual Explaining the Theory and Operation of Heat-Flow Measuring Equipment by F. S. Birch. (Contract Nonr-4029)

CRUISES

Use of Vessels

Cruise No. and Sponsor	Date	Work Area	Principal Investigation	Chief Scientist
CHAIN 60 NSF-GB4431 GP5319	18 May 1966 30 June 1966	Atlantic Ocean, Caribbean Sea and Gulf of Mexico	Echo-sounding, mid-water sound scattering observations, surface temperatures, bt's, plankton tows, mid-water trawling.	R. Backus
CHAIN 61 Nonr-4029	11 July 1966	N. Atlantic Ocean, Mediterranean and Red Seas	Hydrographic stations, velocimetry, thermometry, bathymetry, photography, sea floor sampling, heat flow measurements, sea-floor reflectivity, continuous seismic profiling, gravity and magnetic measurements.	E. Hays E. Zarudzki J. Hunt J. Phillips
ATLANTIS II, No. 21 Nonr-4029 and Nonr-2866	24 May 1966 27 May 1966	N. Atlantic Ocean	Testing Gear	J. Beckerle
ATLANTIS II No. 22 Nonr-4029, Nonr-2866	10 June 1966 3 Aug 1966	Atlantic Ocean Caribbean Sea	Sound velocity profiling, internal wave measurements, echo sounding	J. Beckerle R. Payne
GOSNOLD 94 Nonr-4029	13 Oct 1966 17 Oct 1966	N. Atlantic Ocean	Line hydrophone tests	S. T. Knott

CHAIN #61, Woods Hole - Lisbon (Dr. Hays)

CHAIN departed Woods Hole about 1030, 11 July 1966, bound for Lisbon along a northern route. Heavy fog was encountered immediately south of Nantucket and persisted for several days reducing speed of advance. After steaming easterly through the fog, a great circle course was taken towards an area 500 miles west of Ireland. In this area CHAIN participated in MILOC 66, a study of the area by several NATO countries.

Two stations were made enroute to the area to test equipment and check out personnel in operations. A sound velocimeter lowering and a hydrographic cast were made. Quartz thermometers were measuring temperatures at depths of 5 meters and 30 meters. Bathymetric, magnetic, and gravimetric measurements were made along the track.

During the NATO exercises CHAIN made 15 sound velocity profiles, 13 hydrographic casts, 14 current meter lowerings, took 123 BT's and towed the GEK for current measurements during transits from station to station. All data except the sound velocity profiles were worked up and sent to La Spezia which is acting as the coordinating center. The sound velocity data are being processed now.

The last 36 hours of the exercise were used in monitoring currents as measured by three drogues. These were retrieved and CHAIN steamed directly to Lisbon, arriving on 29 July as per schedule.

CHAIN Cruise #61 (Mediterranean) (Mr. Zarudzki)

This leg of the cruise was planned to achieve specific acoustical, geophysical, geological and oceanographic objectives in the Eastern Mediterranean. The acoustic and oceanographic objectives were investigations of the vertical distribution of the velocity of sound and temperature throughout the water column, and nephelometry and particulate matter studies aimed at elucidation of the water structure and the transport of sediments. The near-surface sea water salinity and temperature observations were also to be taken to help tie continuous underway studies of the water temperature by towed sensors with bathythermograph data.

The objectives of underway geophysical investigations of the sea-floor and the underlying strata included high resolution bathymetric measurements, continuous seismic profiling using two sound sources (the 100, 000-joule sparker and the Bolt air gun) as well as, the measurements of the earth's gravity and total magnetic intensity fields. On stations the sea-floor was to be photographed with a WHOI stereoscopic underwater camera system and an oblique Thorndike camera. Dredge and core samples, the latter accompanied by heat flow measurements, were to be taken for geological and acoustic studies of the sea floor.

The tracks of the cruise, the location of stations and the program for the "underway" and "on station" measurements were chosen to supplement data previously collected by the WHOI and the Lamont Geological Observatory expeditions to the Mediterranean. The program covered the Sicilian Escarpment, the sedimentary basins of Ionian, Aegean and Levantine Seas and the Mediterranean Arc structures. A study of selected volcanic seamounts and a geophysical investigation of the active volcano of Thira (Santorini) was also planned.

The Mediterranean part of the cruise (legs 2, 3, and 4) started from Lisbon on August 2, 1966 and ended in Beirut on October 5, 1966. During the 58 days at sea 7347 nautical miles of track (see Figure 1) were covered in carrying out simultaneously continuous geophysical measurements, i. e. bathymetry, continuous seismic profiling, gravity, and magnetics. In all, 50 stations were occupied during that period, at which 160 individual lowerings were performed. These included: 37 velocimeter lowerings; 38 nephelometry stations; 38 Thorndike bottom camera stations; 13 bottom current station; 1 dredge station. 31 cores of a total length of 178 meters; 31 heat flow measurements; and 8 WHOI underwater camera runs. The overall daily work averages were: underway observations, 19 hours 55 minutes; on station observations, 4 hours 5 minutes; cruising speed, 6.5 knots. The interim ports of call were: Piraeus and Rhodes. About 92% of the program initially proposed for the cruise has been completed. Instrumental breakdowns were responsible for approximately 8% of the program loss. The weather was favorable throughout the cruise.

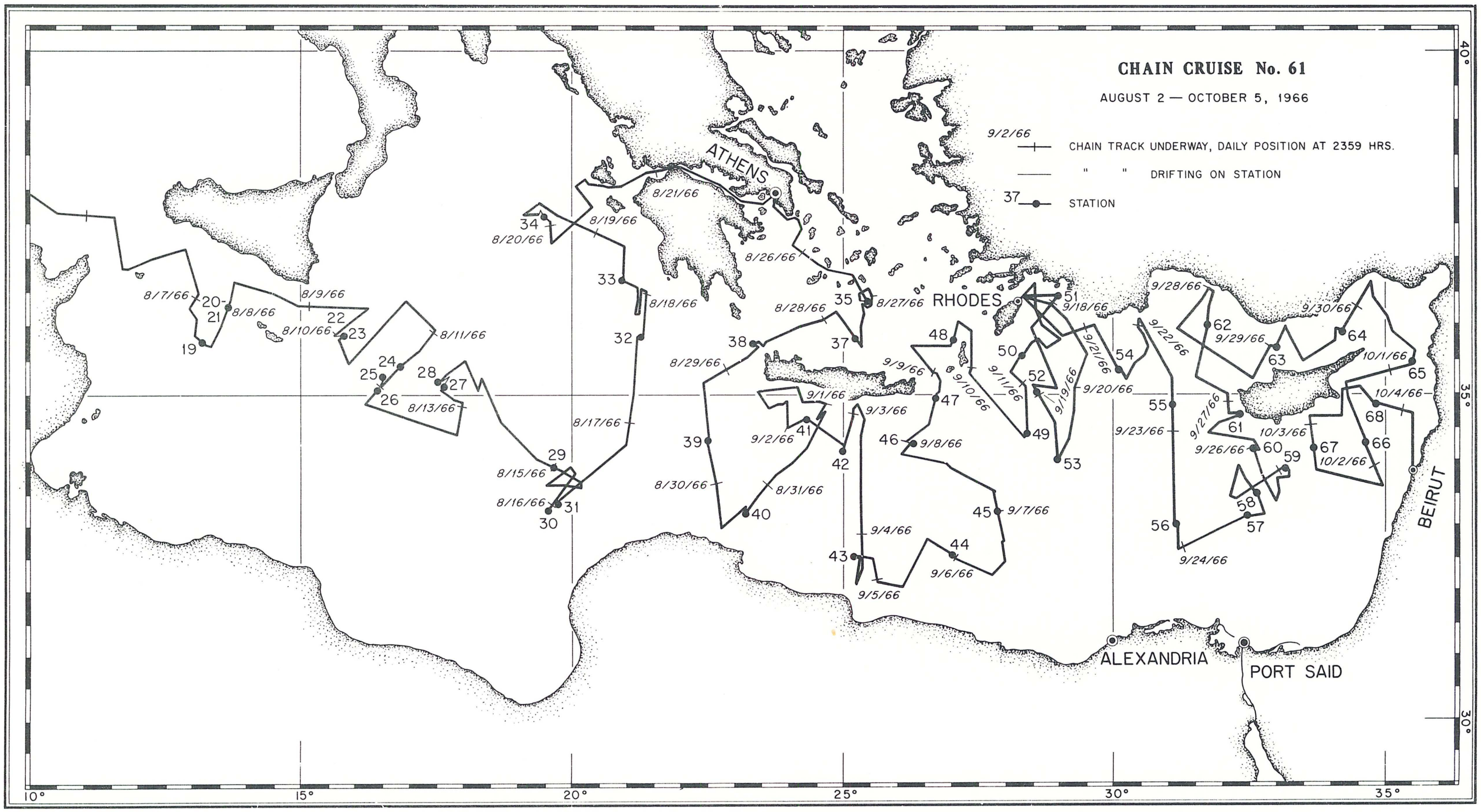

Figure 1. Cruise Chart of CHAIN 61.

CHAIN #61 - Beirut - Port Sudan (Dr. Hays).

An area near 21°20'N, 38°E has been observed to contain water of an anomalous temperature of 56°C at a depth near 1050 fathoms. These measurements had been made while the observing ships were in transit through the Red Sea and could not devote enough time for studying the area thoroughly. The National Science Foundation funded a six weeks study of this area and this became part of CHAIN Cruise #61.

CHAIN departed Beirut 10 October 1966 (one day behind schedule due to clearance required for a scientific shipment) and arrived at Port Sudan 27 October 1966.

Two short seismic profiling runs were made at the junction of the Red Sea, the Gulf of Aqaba, and the Gulf of Suez. Near this junction the Bouguer gravity anomaly changes sign and the subbottom profiles are of particular interest. Bathymetry, total magnetic field intensity and gravity were measurements made on all transits of CHAIN while in the Red Sea.

At the hot-hole location buoys were set for radar navigation and the topography of the area determined. Then a detailed sampling of the area followed. This included: free fall cores to obtain shallow surface sediments along specific tracks; gravity cores with heat flow apparatus attached to determine the heat flow pattern; piston cores also with heat flow apparatus to obtain deeper sediment samples; Kastenlott cores to obtain undisturbed sediments to depths of four meters so that the sediment layering could be correlated over the area; many hydrographic casts to obtain water samples throughout the area, (so mineral distribution could be studied) a large (1000 liter) water sample of the 56° water for C^{14} and uranium series analysis; water samples collected in a sterile manner for bacteria samples; and many lowerings of a temperature pinger that give temperature of the water versus height above the bottom. In addition seismic profiling, magnetic and gravimetric measurements were made in the area above and around the hot hole.

Considerable analysis for heavy metals took place aboard the ship. Samples were also prepared for isotope determination. Bacteria cultures were attempted from the hot water. Some bacteria were found at the brine-normal Red Sea interface and were cultured only at temperatures exceeding 40°C. The 56° water was sterile, however, the first such place ever found in the ocean to our knowledge.

An immediate interpretation of these results suggests the hot-hole to be the location of a now quiescent volcano that erupts or perhaps geysers periodically supplying the heated water enriched in heavy salts by a percolation process.

ATLANTIS II Cruise #22 (Dr. Beckerle and Mr. Payne).

Cruise 22 of ATLANTIS II, June 10 to August 4, 1966, was devoted primarily to sound-velocity-profiling in the waters between Bermuda and the Antilles. It was funded under the Office of Naval Research contract Non-2866 and a grant from the National Science Foundation funded a major portion of the ship costs. However, the research is pertinent also to Nonr-4029. A track chart is shown in Figure 2.

Earlier sound velocity profiling cruises were made to this area in July 1962 by ATLANTIS (Cruise #282), in July 1964 by ATLANTIS II, (Cruise #11) and in April 1965 by CHAIN (Cruise #47), and revealed large scale horizontal variations in sound velocity at 800 meters depth. These are believed to reveal the existence of "internal" Rossby waves in the ocean. During the cruise this summer, a study was made of the thermal front region located at about latitude 30° N, southwest of Bermuda. A temperature sensor was towed and a line of sound velocity profile (SVP) stations was placed as shown on the ship's track through this region. In addition, preliminary tests for internal ocean waves were made in the seasonal thermocline using the sound velocity profiling system. This test experiment was carried out close to Bermuda to allow radar fixes on Argus Island. A portion of this cruise was a cooperative study of the acoustical environment with Hudson Laboratories of Columbia University and Bell Telephone Laboratories.

On the technical side of the cruise, we demonstrated the feasibility of obtaining sound velocity profiles using an on-line computer with the WHOI velocity profiling system. The computer was a PDP-5 that has been used on earlier cruises of ATLANTIS II by A. R. Miller from the Physical Oceanography Department. The development effort for the on-line system was undertaken by staff members of the Applied Research Laboratory of the Sylvania Electronics Products Corp. in Waltham, Massachusetts at their own cost. Their engineers designed and constructed a logical signal processing circuit to improve signal detection and tracking of the echo from the inverted echo sounder in the underwater instrument package and their mathematicians developed the on-line

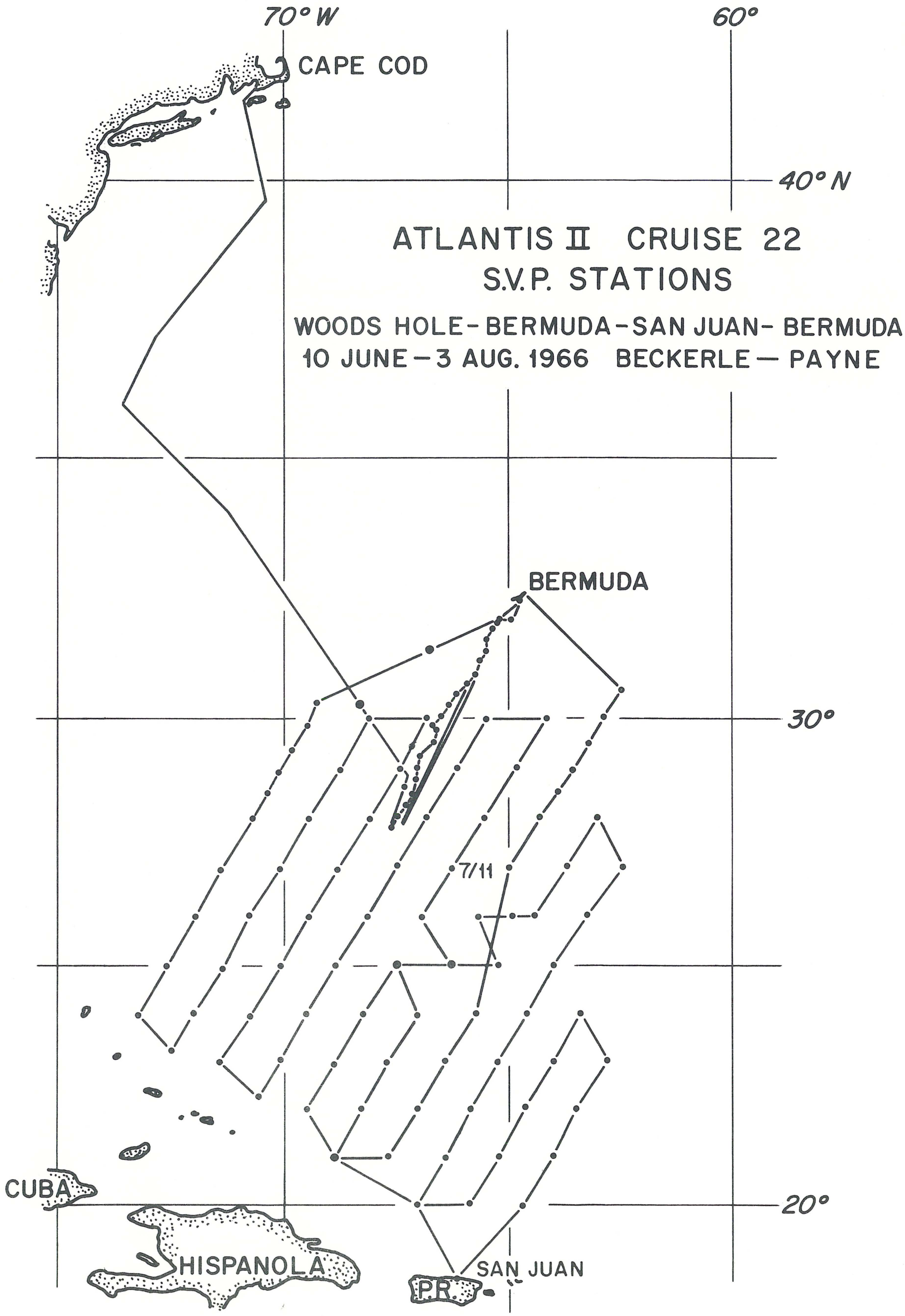

Figure 2. Cruise Chart of ATLANTIS II, Cruise No. 22.

computer program for the PDP-5 computer under consultation with the Geophysics Department. This computer program and other parts of the system were tested on a short 4-day cruise, ATLANTIS II #21. Several specialists from Sylvania participated on both of these cruises.

117 SVP stations were made on a triangular grid with a spacing of about 65 nm. This summer's coverage was broader and on the average, more detailed than either of the previous surveys and should serve to resolve some of the features indicated in contours of the data from the other cruises.

Measurements taken in addition to sound velocity included temperature at the surface and at a depth of about 130 m. Hourly BT's were made throughout the cruise.

Cruise Report, GOSNOLD 94 (Mr. Knott).

A cruise of a few days was taken in mid-October to make further tests of various types of hydrophones. In the course of this work a high-resolution, seismic profiling run was made down the meridian, 71°West. What we believe to be glacial pressure ridges, and a berm-like outwash feature found 20 miles south of Martha's Vineyard on earlier cruises (BEAR 192 and 221, 1958 and 1959) were found to extend westward to 71°W.

TASK UNIT I - OCEANIC ACOUSTICS

Work Unit - Sound Transmission

Generalized WKB Methods Applied to Diffraction Effects (Dr. Murphy).

During this reporting period an analytical study was begun of diffraction phenomena that may be associated with turning points on a sound ray in a medium with a spatially varying sound velocity (see Note 1 below).

Since the turning point region is a region where geometrical optics fails (there are no valid asymptotic expansions for the exact solution), the ingredients that lead to this failure may give rise to mechanisms exhibiting a high sensitivity to perturbations of the medium properties in this region. Therefore, it is of particular interest to examine special diffraction effects that may be associated with turning point regions. It would be expected that if such effects do arise and are significant, in turn, they should be very sensitive to perturbations of the medium properties in the turning point region.

The so-called generalized "WKB-type" approximation (see Note 2 below) is used in the analysis. The ordinary WKB-method, which leads to a geometrical-optics formalism, fails in the immediate neighborhood of a turning point, whereas the generalized WKB-type approximation, with certain limitations, can be designed to be valid in a configuration giving rise to a number of turning points.

As a first step in the study, the generalized WKB-type approximation has been applied in an analysis of the "split-beam" sound field as shown in Figure 3. In this figure, $C(Z)$ represents the sound velocity as a function of depth Z. The solid lines represent rays constructed according to Snell's law, including the "split-rays" OE," OD" and OC". The generalized WKB method was applied using Weber functions (see E. T. Whittaker and G. N. Watson, "A Course of Modern Analysis", The Macmillan Company, New York, 1947, p. 347) to construct approximate solutions valid in the entire range of Z including the two turning-point regions for each ray. The extension of the analysis to include two turning-point problems opens up the possibility of treating, in this convenient way, sound channel problems, as well as the split-beam pattern, and other non-monotonic velocity profiles.

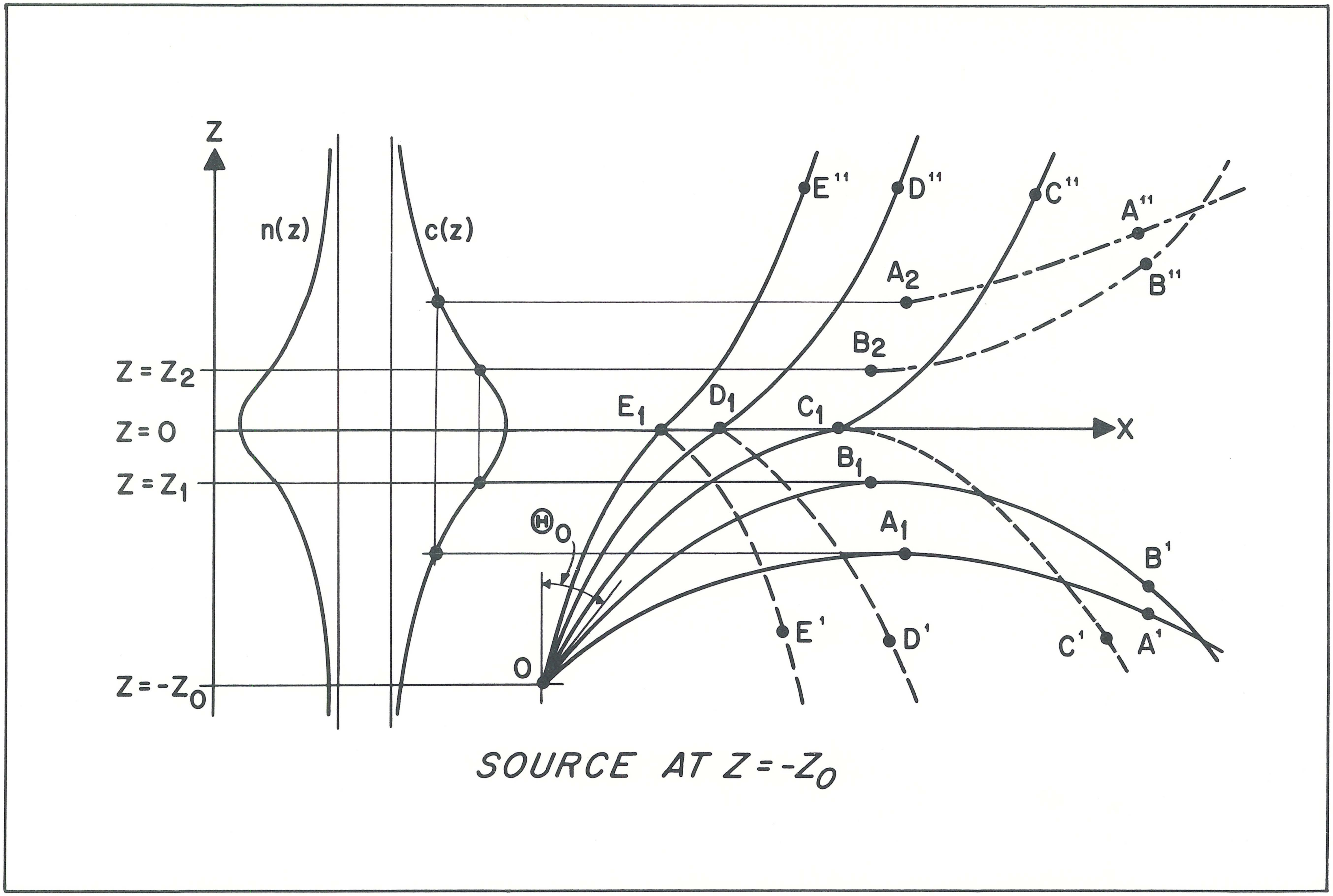

Figure 3. Diffracted Rays in Split-Beam Sound Field.

Although the Weber functions are exact solutions for a parabolic velocity profile, with the generalized WKB-type procedure a scheme is developed to "distort" these functions to approximate solutions for somewhat more general profiles. It may, in turn, represent a convenient way to examine the sensitivity of the results to specific changes in the velocity profile.

In some regions of the XZ – plane for which asymptotic expansions for the generalized WKB-type approximations are valid, an equivalent ray representation may be introduced. Some of these will be the usual geometrical-optics rays (solid lines in Fig. 3) but there may be additional regions of valid ray representation. It is then possible to introduce "diffracted rays" in these regions, associated with these diffraction effects, and to obtain quantitative connections between the amplitude of these diffracted rays and the usual geometrical-optics rays.

The analysis for the split-beam, or two turning point problem, is nearing completion and details will be given in a separate report. The dashed curves in Figure 3 are intended as an indication, based on preliminary results, of "reflected diffracted-rays" (i.e., segments E_1E', D_1D' and C_1C') and "transmitted diffracted rays" (i.e., segments A_2A'' and B_2B'') for which quantitative connections with the ordinary geometrical-optics rays (solid curves) have been obtained.

Although a ray representation for diffraction effects is of some interest, for a thorough examination of turning point phenomena it will be necessary to retain the complete generalized WKB-type results and examine the configuration with the receiver actually located in the turning point region. The extension of the analysis to some of these problems is in progress.

Note 1: In a medium with sound velocity $C(Z)$ a function of Z only, the ray path is given by Snell's law

$$\frac{\sin\theta(Z)}{C(Z)} = \frac{\sin\theta_0}{C_0} \tag{1}$$

Where $\theta(Z)$ is the angle of the tangent to the ray measured with respect to the positive Z-direction. The subscript o refers to values at some reference level $Z = -Z_0$. The ray turns around $(\theta = \pi/2)$ at a level Z_t

given by

$$\frac{1}{C(Z_t)} = \frac{\sin\theta_0}{C_0} \tag{2}$$

In general, any depth for which Eq. (2) is satisfied is called a turning point for the θ_0 - ray.

Note 2: "WKB" refers to the so-called Wentzel-Kramers-Brillouin approximation; see, for example, P. M. Morse and H. Feshbach, "Methods of Theoretical Physics", Vol. II, McGraw-Hill Book Company, Inc., N. Y., 1963, p. 1092. For the "generalized WKB-type" approximation, see S. C. Miller, Jr., and R. H. Good, Jr., Phys. Rev. 91, 174 (1953).

Sound Transmission NE of Bermuda (Mr. Doutt).

Data from BEAR Cruise 167 consists of successive measurements of pressure levels at a vertical string of five hydrophones for successive ranges up to 10,000 yards from an explosive source. Adequate bathythermograph data were obtained to verify the stability of the temperature profile during each run.

From these data, energy levels as a function of range and depth have been computed for various frequencies. Velocity profiles have been calculated using the temperature information and an average temperature versus salinity curve for the area of interest. A new computer program has been written for the GE 225 which will calculate the energy level at any specified range for a point source and an arbitrary velocity profile. These theoretical calculations can then be compared with the experimental data.

Diffraction and Interference Effects in Underwater Sound Transmission (Mr. Baxter and Mr. Brockhurst)

Officer (1958) states that the ray theory is applicable to sound transmission measurements if the fractional change in the velocity gradient over a wavelength is small compared to the ratio of the sound velocity to the wavelength, that is $\left|\lambda_0 \frac{\delta c'}{c}\right| << 1$. Analysis (WHOI Ref. No. 66-43, 1966) of deep ocean sound transmission measurements (Baxter, Brockhurst and Hays, 1964) has shown (Baxter and Brockhurst, press) that appreciable diffraction effects in convergence zone transmission are found if $\left|\lambda_0 \frac{\delta c'}{c}\right.$ is greater than

5×10^{-4}. During the period 1 May 1966 - 31 October 1966 we completed our final draft of a journal publication (Baxter and Brockhurst, 1966) on this subject. This paper has been accepted for publication in December by the Journal of the Acoustical Society of America.

At the completion of this work, we commenced to study available data on conditions in the Baltic Sea south of Gotland in preparation for sound transmission measurements planned for a cruise of ATLANTIS II in May and June of 1967.

Data taken in June 1966 by the Danish research vessel HENRICK GERNER indicate that the temperature and salinity gradients in the southern part of the Baltic produce a sound channel having an axis depth of 50 meters. There is a ridge rising south of Gotland to a water depth of about 35 meters. This ridge divides the region into two relatively flat areas where the water is about 100 meters deep. On the western side of the ridge, the bottom water (which originates in the North Sea) is more saline than that on the eastern side. In the western area, the gradient below the sound channel is steeper and the velocity of sound at the bottom is greater. The surface water in both areas is the same (with salinity of about 7.5 o/oo).

Dr. Frank Mannheim, who has studied the geology of this part of the Baltic, tells us that below the flat areas there is a layer of soft mud, glacial clay, and sand which has been sounded acoustically and found to be about 100 meters thick.

These conditions, the strong sound channel and the deep layer of soft sediment, will probably produce interesting shallow water transmission effects with closely spaced convergence zones at high frequencies and short ranges, and normal mode effects at lower frequencies and longer ranges. Because of the continuous variation of the velocity of sound in the water column, the version of normal mode theory discussed by Tolstoy & May (1960) and Tolstoy(1964) will be more applicable than the simple theory of Pekeris (1948).

In studying the theory of modes in continuously varying media, we noted that the transmission versus range computed by Tolstoy (1964) for convergence zone transmission in the deep ocean is similar to that which we measured in the Mediterranean. It is interesting that Tolstoy's normal mode theory is also applicable to convergence zone studies where sharp gradients exist. If we develop a program for mode computations for the Baltic experiments, it may also be useful to reexamine the Mediterranean data in more detail.

Studies of the Effects of Currents on Acoustic Transmission (Mr. Nowak).

Since the propagation of sound is affected by the properties of the ocean, the possibility of measuring these properties by measuring propagation changes suggests itself. For example, the time required for sound to travel between two fixed points is less if the sound moves with a local current than if it moves against the current.

An experimental range has been set up in the water between the WHOI dock and an adjacent dock. Transducers at each end of a 150 ft. sound path alternately send and receive short - 32, 64, or 128 cycles - coherent bursts of 12.5 khz sound. The phase of the received signal at each transducer is compared with the phase of a master oscillator supplying the coherent 12.5 khz through the use of two VLF phase tracking receivers. The phase difference between the signals from each receiver is used as an indication of the magnitude of the average current encountered by the sound in traveling between the transducers. Records of this phase difference have shown fluctuations with amplitudes and directions such that they could be produced by the currents flowing through the sound range. The currents were roughly monitored with small drogues at first. A savonius rotor and direction vane unit were installed in order to get more quantitative assessments of the currents. Only a short period of simultaneous recording with these two systems was possible because of fouling of the rotor and electronic troubles with one of the dock mounted units. It was decided to rebuild the electronics to eliminate the electronic troubles and provide for a longer path experiment. These modifications are being made at the present time.

Seismic Reflection Analysis (Sea Spider). (Mr. Olmsted and Dr. Beckerle)

During evaluation of the Sea Spider installation on the Blake Plateau in August 1965 several oblique seismic reflection records were obtained using hydrophones attached to the legs of the Sea Spider structure. The sound source used was the 100,000-joule sparker aboard CHAIN. The PGR records contained the variable density recordings of the hyperbolic range versus travel time curves from the multiple bottom and surface reflected sound paths through the water layer. However, analysis of these data has been hampered by a ringing noise characteristic of the recorded signals which has remained unexplained. We believe some improvement in the technique of mounting the hydrophones on the cable is necessary. Some of the records suggest that the hydrophone near the large sub-surface buoyant float may require special consideration to avoid echo interference from the float.

Magnetic tape recordings of these oblique seismic records were examined (as mentioned in WHOI Ref. No. 66-43) to determine whether an extensive correlation analysis between direct arrivals and arrivals reflected from the bottom and sub-bottom would be profitable. We conclude that an extensive study is not waranted because of the character of the noise on the recordings.

Work Unit - Sound Scattering

Midwater Sound-Scattering Integrator (Dr. Backus and Mr. Wing).

In order to study better the geographic variation in midwater sound scattering we have built an apparatus that measures 12-khz scattering in the upper 400 fathoms of the water column. This depth interval encompasses most of the agents responsible for volume reverberation.

The apparatus is used as an attachment to the Precision Graphic Recorder and other elements of a 12-khz echo-sounding system. When the apparatus is used, the PGR is operated on the 400-fathom sweep or any slower sweep. The apparatus sums the integrating scattering from 100 sweeps of the PGR and displays the result on a digital voltmeter. Outgoing signal and bottom echo are excluded by gating. The signal voltage generated during any one sweep of the PGR is squared with time in order to compensate for spreading losses. The sum of the integrated voltage is corrected by subtracting a figure representing the ambient noise. This figure is determined by operating the sound-scattering integrator for 100 sweeps of the PGR with the echo sounder transmitter turned off.

A preliminary version of the apparatus was tested at sea during CHAIN Cruise 60. As a result of this experience a refined apparatus is being built.

Work Unit - Ambient Noise (Mr. Schevill and Mr. Watkins).

In the laboratory we have continued our study of high-latitude ice-field ambient, with analysis of tape recordings from the Bering Sea and the Canadian Archipelago supplied by U. S. Navy Electronics Laboratory, U. S. Navy Underwater Sound Laboratory, Canadian Pacific Naval Laboratory, and Dr. Carleton Ray, and from the Ross Sea (C. Ray and ourselves).

We are completing a report on reactions and responses of Antarctic seals to playback of their own calls (supported jointly by USARP, NSF). We had temporary success in apparently persuading the wild seals that the playback represented another individual.

Sound produced in air from humpback whales (Megaptera novaeangliae) have been compared with the familiar underwater sounds of this whale. The sounds of normal blows are largely inaudible underwater, but the relatively unusual purposeful wheeze produced in air at the blowhole couples well to the water. A report of this phenomenon is in progress.

Directionality of low-frequency (250 to 500 cps) echo-ranging clicks of killer whales is discussed in our newly-published report. The main lobe seems to be at most 40°, and probably less.

TASK UNIT II - PHYSICAL OCEANOGRAPHY

Work Unit - Physical Properties

Analysis of CHAIN 47 Sound Velocity Data (Dr. Beckerle and Mr. Bergstrom).

Sound velocity profiles were obtained along a 300-nautical mile line southwest of Bermuda in April 1965 during CHAIN Cruise 47. The scatter of sound velocity measurements for these sound velocity profiles has a region of small scatter (a node) at 1800 meters depth, Figure 4. Possible explanations for this observation include the following: a) The node in the scatter of points may be evidence for the depth of no motion required to evaluate geostrophic currents from hydrographic data. b) The node in the observations might be due to internal waves in the ocean. c) The node in the observations at 1800 meters

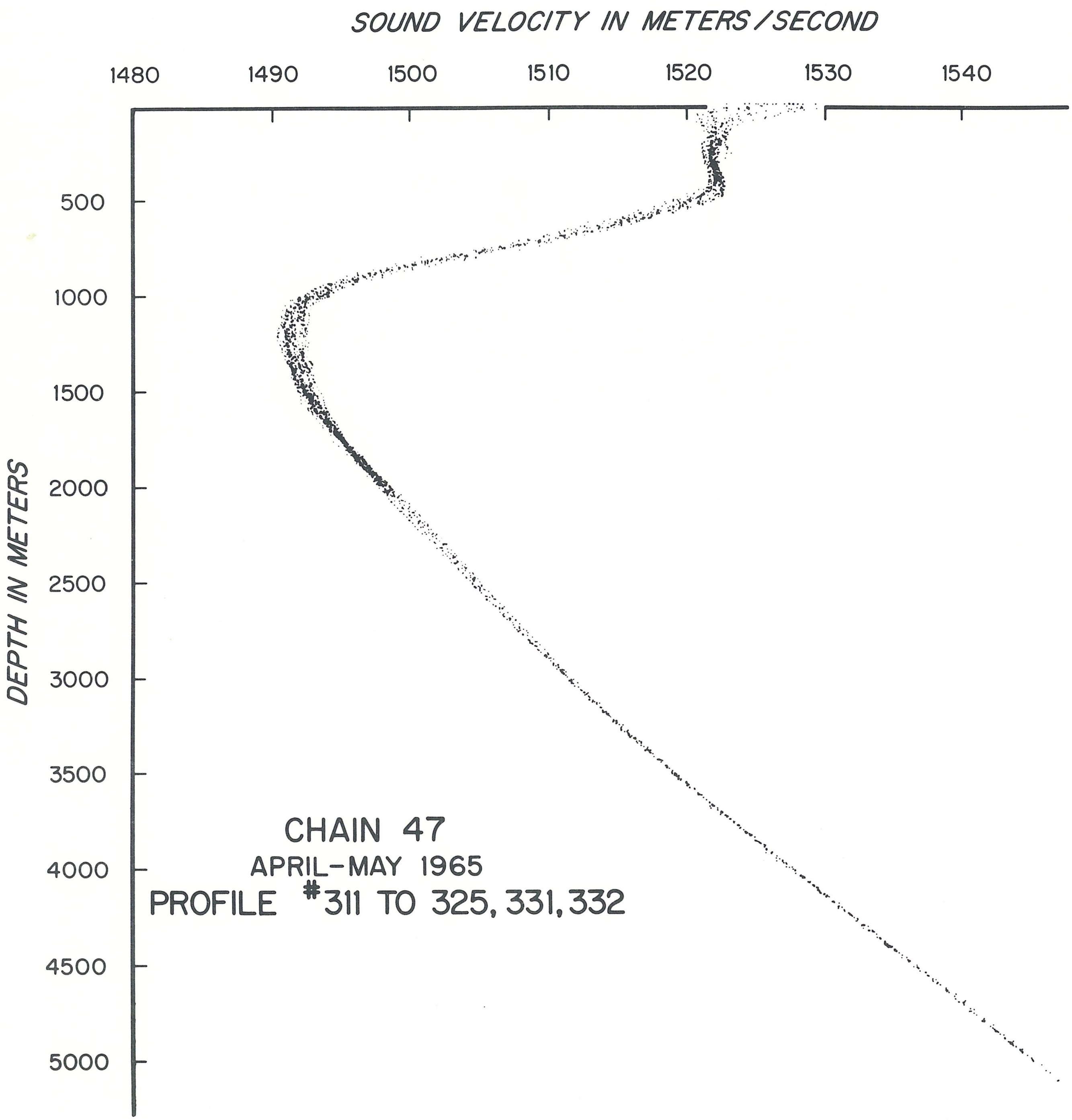

Figure 4. Sound Velocity Measurements.

may be evidence for the constant depth isotherm expected according to Sverdrup (Defant, 1961) along the north-south meridional section at this depth and location in the Atlantic Ocean. The process responsible is lateral and vertical mixing of large water masses along isopycnic surfaces which rise as they approach polar regions. The location of the constant depth isotherm near latitude 30°N is attributed to an asymmetry of the temperature contour pattern caused by the very cold, extensive Antarctic water. These three as well as other explanations are being examined.

Sound Velocity Measurements (Dr. Beckerle and Mr. Olmsted).

A computer-velocimeter, real-time, data-acquisition and processing system was installed on the ATLANTIS II cruise #22. Work has been done both with this system and with the data so acquired. The system has been studied with the aim of increasing its capabilities and standardizing its operation so that it will become a reliable velocimetry tool.

In addition, a set of programs has been written to perform off-line processing of the data taken during ATLANTIS II cruise #22. These programs utilize the GE 225 computer to calculate sound velocity profiles from the magnetic tape output of the shipboard system. The profiles are kept in a variety of forms (punched cards, printed lists, and magnetic tapes) so that they may be conveniently displayed and/or subjected to further analysis.

Analysis at Sea of a Line of Sound Velocity Profiles Southwest of Bermuda (Dr. Beckerle and Mr. Payne).

During the sound velocity profiling cruise of ATLANTIS II #22, this summer, the sound velocity profiles were analyzed with an on-line computer. The profiles taken on a line southwest from Bermuda revealed a pronounced bulge, an upward shift of over 200 meters in the main thermocline region. The bulge which extended over a range of 60 n. m. was located just north of latitude 28°N which is known to be the boundary of a thermal front zone, as well as the southern boundary of a region of marked increase in marine life. This finding fulfilled one of the purposes of the cruise which was to look for additional confirming evidence of the deep transition region in the sound velocity structure reported earlier in this report (p. 12).

Deep Towed Temperature Sensor Observations (Dr. Beckerle).

The pronounced bulge in the thermocline region revealed by the line of sound velocity profiles on ATLANTIS II cruise #22 was also examined using a towed temperature sensor on a fish as an independent check on the existence of the bulge. The towed fish contained a quartz thermometer and an inverted echo sounder. The fish was periodically raised and lowered every 10 minutes between 200 and 400 meters during the tow by changing the ship's speed. The ship's average speed was about 8 knots. Standard BT's were also taken from the surface to 200 meters during this work. The temperature observations are shown in a contour chart, Figure 5. There is a pronounced rise in the contours in a region where the temperature gradient is weak which emphasizes the sensitivity of the technique. The bulge in the temperature contours was found to be in the same region as that observed from the sound velocity profiles.

Test Measurements of Internal Wave Fluctuations with Sound Velocity Profiling System - Yo-Yo-Experiment (Dr. Beckerle).

During ATLANTIS II, Cruise #22, sound velocity profile measurements were also obtained by raising and lowering the velocimeter instrument package every 2.7 minutes through the depth interval of 50 to 250 meters. These observations revealed a 16-minute period internal wave as well as waves having longer periods. In addition to these results, on raising the instrument we found the depth of a sound velocity measurement to be slightly shallower than when we lowered the instrument. This difference was attributed in part to the manner in which the sound velocimeter was mounted in the instrument package; apparently some water was carried along with the apparatus a small distance when the instrument was being raised. Tests which confirmed this explanation were carried out in a water tank. This measurement problem can be corrected by mounting the sound velocimeter in a manner that will permit the free flow of water through it. In view of this difficulty we were unable to attribute fluctuations with measurements of 5-minute periods to internal waves. However, much longer period fluctuations were observed and could be considered to be evidence of internal waves.

Long-range acoustical experiments between fixed source and fixed receivers carried out several years ago exhibited fluctuations in the order of minutes. It was suggested that those acoustical fluctuations were caused by internal waves. Since that time, calculations were made of the minimum period of vertical oscillations in the main and seasonal thermocline in the

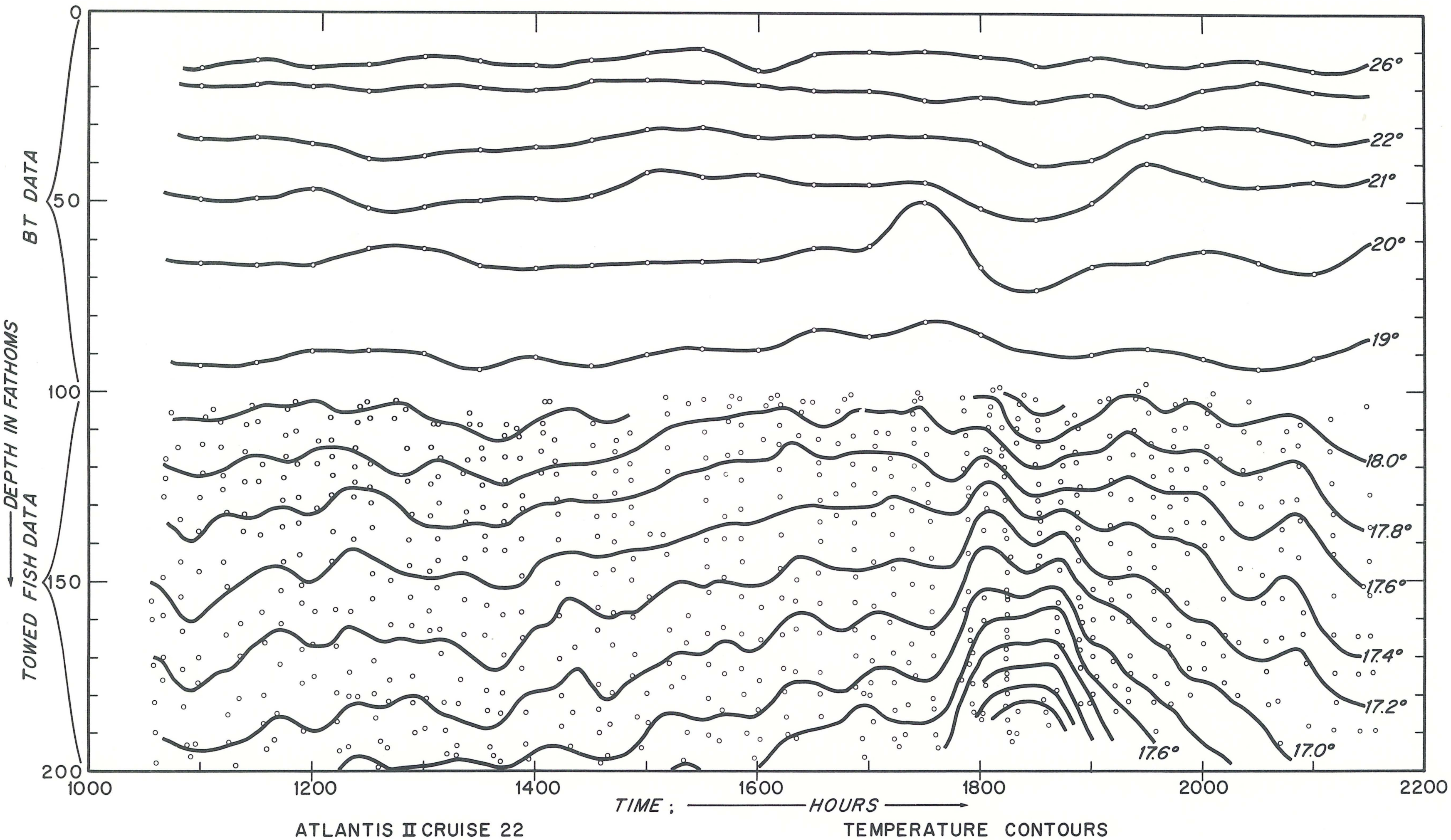

Figure 5. Temperature Cross Section.

Bermuda area from hydrographic observations. These calculations produced periods of 4 minutes and 16 minutes giving support to the conjecture that internal waves were responsible for the acoustical fluctuations. Measurements of the internal wave fluctuations described above with an on-line sound velocity profiling system give further support to this role of internal wave movements on the fluctuation of acoustical transmission. In order to relate the degree of correlation between acoustical and environmental experiments further studies require simultaneous measurements.

<u>A Surface Temperature Sensor</u> (Mr. Dow, Mr. Leonard and Mr. Scott).

During the Mediterranean Cruise #61 of CHAIN an effort was made to measure temperature in the top few inches of sea water while underway. To accomplish this a small sea-sled was developed which follows with remarkable fidelity the undulations of even a choppy sea. A thermistor was fastened to this sled and was connected via an electrically conducting tow cable to the ship. The sled was towed from the end of a long pole secured to the starboard rail at the bow, to keep the sensor clear of bow wave turbulence. The electrical line to the thermistor was terminated in a stabilized transistor bridge circuit mounted in the ship's laboratory. Strip chart recorders provided the final readout of temperature. The system was constructed and used extensively between Athens and Beirut.

Such a sea-sled appears to have many advantages in the study of the thin air-sea interaction water layer.

<u>Deep Towed Temperature Probes</u> (Mr. Dow, Mr. Witzell, Mr. Scott, and Mr. Grant).

Two towed bodies were designed for towing temperature probes to depths up to 900 feet. Each was provided with a quartz thermometer probe and a 50 kc echo sounding transducer beamed toward the sea surface. This equipment was connected to the ship via a special double armored towing cable containing four coaxial lines. The temperature probes were read out on counters and strip chart recorders in the ship's lab., and the transducers were connected to short pulse echo sounders on board. The round-trip travel times of an acoustic pulse between the transducer and the ocean surface provided accurate and continuous measurements of the fish depth.

The fish towed from ATLANTIS II, Cruise #22, was also equipped with a hydrophone and high gain preamplifier unit. This hydrophone was used in acoustic transmission experiments between ATLANTIS II and other ships and Bermuda.

The fish towed by CHAIN, Cruise #61, was operated successfully from Woods Hole to Beirut. However, the quartz thermometer probe finally succumbed to severe corrosion. This can be corrected only through a design modification by the manufacturer.

All components of the towed body are readily available materials. The materials are, steel pipe, pipe cap, tubing, straps, bolts and lead. There is a minimum of machine work and the weight of the fish can be controlled by the amount of lead poured in the body.

TASK UNIT III - SEA FLOOR PROPERTIES

Work Unit - Sea Floor Structure

Preliminary Results Obtained during CHAIN Cruise #61 in the Mediterranean (Mr. Zarudzki).

During CHAIN Cruise #61 in the Mediterranean a great volume of acoustical, geophysical and oceanographic data was acquired. It will be analyzed and reported in appropriate task and work unit subdivisions throughout the 1967/68 period.

However, some interpretation of geophysical data was carried out on board ship during the cruise. Our work along the Sicilian escarpment confirmed and elucidated many aspects of its complexly faulted origin and subsequent sedimentation processes. The seamount complex off Libyan coast showed its dual sedimentary and volcanic character. It was the only place in the Mediterranean where we succeeded in photographing sediment-free hard rock outcrops, in this case at a depth of about 1000 fathoms.

The western approaches to Greece, across the zone of maximum regional seismicity (Galanopoulos, personal communication) revealed several complex structural features i. e., fault scarps, tilted sedimentary basins, etc.

caused by continuing tectonic activity. Noteworthy is the absence of any magnetic anomalies caused by plutonic activity associated with the tectonics of Greece.

The investigation of the Thira caldera, however, revealed one of the strongest (approx. 1000 gammas) magnetic anomalies in the Mediterranean. This anomaly appears to be associated with the group of central vents now forming an island of Nea Kaimeni. Remarkable correlation of the bottom morphology, and the total magnetic intensity, obviously controlled by the past volcanic activity, was noted. This is interpreted as an indication of ancient basaltic intrusions in the form of lava flows and volcanic vents, and led to the discovery of an old submerged volcanic vent on the outside of the southern rim of the caldera.

During the study of underwater sills between Crete and Karpathos, elevated sedimentary basins were found on the tops of tectonically controlled sills. These basins appear to have been filled by several different, some possibly yet unknown, sedimentary processes, and lie at an elevation of 400 fathoms to 500 fathoms above the adjacent abyssal plains.

Sound Source (Mr. Witzell).

A Bolt Associates air gun was purchased to be used as an underwater sound source for continuous seismic profiling studies. The gun was tested dock-side and then installed on the R/V CHAIN with appropriate piping and air manifold control system. It is now being used on CHAIN Cruise #61 in conjunction with the present underwater electrical spark discharge method. Tests are being conducted to determine frequency and sub-bottom penetration of the air gun sound source as compared to the spark sound source.

60 Cycle Alarm for Seismic Profiling and Recording (Mr. Witzell and Mr. Church).

On magnetic tape recordings of continuous seismic profiling data, it is necessary to record precision 60 hz from a precision graphic recorder (PGR) on one channel of a multi-channel recorder for playback purposes. Other channels are reserved for data, and voice announcements. The taped 60 hz controls the time base of the synchronous motor which drives the PGR upon playback.

To insure that the precision 60hz signal is being recorded on the tape, a battery operated, transistorized, bell alarm was constructed, which rings if the output signal of the tape monitor jack drops approximately one-half a volt or lower from an initial setting.

Cruise Navigation and Bathymetry Reports; and Compilation of Geophysical and Geological Data (Mr. Dunkle, Mrs. Witzell and Miss Hays

Seven cruise navigation and bathymetry reports were completed during this period. These are reports indicating the location of the various scientific observations made during a particular cruise. The ship's track is plotted on the standard plotting sheet scale.

WHOI Ref. No. 66-2 CHAIN #51; WHOI Ref. No. 66-6 GOSNOLD #73; WHOI Ref. No. 66-7 CHAIN #55; WHOI Ref. No. 66-15 ATLANTIS II #13; WHOI Ref. No. 66-19 Index to Cruises, WHOI Ref. No. 66-38 CHAIN #53.

A manual describing methods now used by the Department of Geophysics in compiling and reporting cruise observations, WHOI Ref. No. 66-20, Manual to Compiling of Cruise Navigation Reports, has been completed.

The compilation of the various types of observations made by the Department of Geophysics over the last ten years has continued. An atlas which will show the location of scientific observations made by the Department of Geophysics is in preparation.

The total of mounted, stereo-pair, bottom photographs held and cataloged at Woods Hole is now 28, 216 and singles, 18, 105.

Our flow camera, which is used to reduce continuous strip records to microfilm size for storage, safe keeping, as well as viewing, has also the capability of changing the vertical-to-horizontal ratios of records. This permits the adjustment of vertical exaggerations in profiles and the like. Of late, in addition to our own work we have photographed and reproduced records for a number of naval and government supported facilities: U. S. N. Underwater Sound Laboratory, New London, Connecticut; U. S. N. Oceanographic Office, Washington, D. C; Lamont Geological Observatory, Palisades New York; and Environmental Science Services Administration (ESSA), Washington, D. C.

Work Unit - Physical Properties of Rocks and Sediments

Sediment Cores from the Eastern Mediterranean Sea (Dr. Chase).

Thirteen sediment cores were taken in the Eastern Mediterranean in August and September 1966, during legs two and three of cruise 61 of CHAIN. The objectives were 1) to sample bottom sediment types, 2) to study the history of sedimentation of the various topographic features of the area, 3) to find the age of subbottom layers, observed in continuous seismic reflection profiles, by coring outcrops of these layers, and 4) to investigate magnetic susceptibility and remanence of the sediments.

The cores were taken between Sicily and Rhodes in depths of water which varied between 200 and 2100 fathoms. Topographic features sampled include sediment ponds, the Central Mediterranean Ridge, the slopes of trenches and submarine hills, and the floor of a volcanic caldera. The lengths of cores varied between three and thirty-five feet. Several of the cores were split aboard ship and described in a preliminary way.

The core from the volcanic caldera of Thira, in the Aegean Sea, consists of pumice gravel and black mud. Highly variable conditions of sedimentation on the Central Mediterranean Ridge, perhaps during the last thirty thousand years, are evidenced by striking differences in color and composition of layers of sediments present in the cores from the Ridge: alternation of periods of stagnation and oxidation is shown by green-black and red layers respectively; volcanic eruptions are evidenced by layers of volcanic ash. In the sediment ponds lie layers of olive-green clay, several meters thick, interlayered with pteropod ooze.

Further analysis is planned after the ship returns to Woods Hole in December 1966.

Tertiary Stratigraphy and Planktonic Foraminifera (Dr. Berggren).

In December, 1965, the Department of Geophysics at WHOI formally incorporated a micropaleontological section within the scope of its research program. As it applies to the work carried on within this department, micropaleontological investigations will be directed primarily towards studying the sedimentary and stratigraphic record preserved beneath the sea and recoverable by means of piston cores taken at selected sites.

Space was allotted for establishing laboratory facilities and they were designed and built. Two major problems faced us at the beginning: a) lack of sufficient scientific literature in the field of micropaleontology; b) lack of comparative fossil sample material to use as a basis for comparison in the course of our normal research work. Although these problems have not been completely solved they have been materially reduced. Literature has been ordered and much has been donated.

A systematic sampling program from the type localities of the Tertiary of western Europe and comparative sections in the Middle East was undertaken during the summer months (1966). This material, which will arrive here late this year, will form the background for all micropaleontological investigations which we shall carry out here in the future. We have been engaged in cataloging and preparing sample material from various areas in an effort to prepare the way for a systematic study of deep sea sediments. In particular we hope to initiate a program of study devoted to the development and distribution of marine planktonic organisms as recorded in the stratigraphic record. Relatively complete sequences are apparently preserved on the slopes of submarine ridges and it is to these that we shall turn our attention at first.

In summary this period has been spent in planning and building facilities for a micropaleontological laboratory and in obtaining the necessary literature and comparative sample material which is the indispensible foundation upon which a research program must be based.

Work Unit - Geomagnetism

Geomagnetic Observations over the Oceans (Dr. Phillips and Dr. Bowin).

More than 3500 miles of magnetic profiles in the eastern Mediterranean were obtained during CHAIN Cruise #61 in an effort to determine the nature of the basement structures beneath the sediments in the region south of Cyprus and Crete. In addition to the above detailed surveys a profile was obtained on the eastward crossing of the North Atlantic to the Mediterranean. Another profile of the mid-Atlantic Ridge and a detailed survey in the vicinity of latitude 30°N has been planned during the return leg of CHAIN Cruise #61. Rock dredges in the axial zone of the ridge and piston cores of the sediment cover of the Ridge flanks will also be attempted for the purposes of determining the age and structure of the Ridges by paleomagnetic and radiometric techniques.

In addition to our shipboard magnetic operations, plans are being formulated to utilize the C54Q aircraft during the next report period for magnetic studies of the mid-Atlantic Ridge in the North Atlantic. However, initial operations will be limited to evaluation of studies of the system in the vicinity south and east of New England.

Magnetic Properties of Rocks (Dr. Phillips).

A rock magnetism laboratory has been established which consists of a spinner magnetometer, magnetic susceptibility bridge, and alternating field demagnetization device. A susceptibility anisotropy device is under construction. Analysis of dredged basalts from the mid-Atlantic Ridge, Puerto Rico Trench, and Barracuda Rise, show that the remanent magnetization component is much larger than that induced in the earth's field, adding further confirmation to the hypothesis that remanent magnetization of rocks in the sea floor is primarily responsible for the observed geomagnetic anomalies. In addition, a flux-gate magnetometer system has been devised to measure the remanent magnetization direction of core samples. Preliminary analysis of the remanent magnetization direction of sediment cores in the Puerto Rico Trench, Outer Ridge, using both the flux gate and spinner magnetometer show that polarity reversals along the core length may reflect reversal of the earth's magnetic field during late Cenozoic time.

Work Unit - Gravity

Gravity Field over Ocean Areas (Dr. Bowin, Mr. Nichols, Mr. Dugan, Mr. Aldrich, Mr. Ruppert and Mrs. Zwilling).

Gravity measurements were made aboard CHAIN 61 during this reporting period on the first two-thirds of the Mediterranean and Red Sea cruise still in progress. These measurements will be particularly important for defining the major aspects of the gravity field in the eastern Mediterranean Sea east of Crete where little data is presently available.

Analysis of our Caribbean gravity data has been continuing, in particular the correlating of the gravity field over the Cayman Trough area and adjoining islands with bathymetric and magnetic field information taken at sea and geophysical and geologic data on the islands. In summary, it appears that the Cayman Trough was developed on the gentle-sloping northern flank of the Nicaraguan Rise by extension of the crust. The initiation of the extension began in the Paleocene or earlier, and the history of development has been complex. The structure is presently growing towards the east. It is also concluded that the Cayman Trough structure is not a westward continuation of the structure producing the Puerto Rico Trench negative free-air anomaly belt.

Our gravity meter (S-13) was returned to the manufacturer, LaCoste and Romberg, Austin, Texas, for repairs and calibration from 22 April to 18 June 1966. Problems which we have had previously with the horizontal acceleration correction and undesirable response to vertical accelerations were corrected during this period, static and dynamic tests under controlled conditions were carried out, and modifications to the system were made. These modifications included signal-noise ratio improvements and replacement of the vacuum tube output stages with solid state units so that the gravity meter impedances would match the IBM 1710 system input impedance more closely.

While the gravity meter was in Austin, the reduction of real-time gravity data at WHOI indicated that the absolute calibration table for the gravity meter might be in error. For this reason, the return trip from Austin was re-routed to cover the Army Map service and Lamont Geological Observatory gravity calibration ranges. These ranges extend from southern Florida to the Canadian Border (in New York State), and cover a range of approximately 1600 mgals. The results of this trip showed that the calibration factor was in error by 0.49 percent. The necessary corrections were made to the calibration table and the computer program.

On 11 July the system was re-installed aboard the R/V CHAIN and left WHOI for CHAIN Cruise #61 to the Mediterranean-Red Sea area. Preliminary analysis of data from this cruise indicate that the modifications made to the system and its calibration were successful in improving static and dynamic performance. The experience gained in the period of this report has clearly shown the need for a static and dynamic test and calibration program of wider scope that heretofore had been thought necessary.

Shipboard Data Processing System (Dr. Bowin, Mr. Ruppert, Mr. Nichols, Mr. Dugan, Mr. Aldrich, and Mrs. Zwilling).

With the essential completion of the real-time program (Mod 8) for our shipboard IBM 1710 computer prior to the departure of the CHAIN's Mediterranean cruise (CHAIN Cruise 61), our attention has increasingly turned to the completion of post-cruise processing and analysis computer programs. The inter-relation of the various processing time and post-cruise computer program is indicated in the accompanying chart (Figure 6). Several of the post-cruise programs are still under development, but we anticipate completion of all of the programs shown in the chart by the end of the year.

A paper (Bowin, 1966) describing CHAIN's shipboard data processing and control system was presented at the Second International Oceanographic Congress, in June at Moscow, U. S. S. R. It was learned from discussions with Soviet scientists that the Soviet Union has no equivalent system.

TASK UNIT IV - ADVISORY ACTIVITIES

Cooperation with Navy Activities (Dr. Hays and A. C. Vine).

During the April - October period there was considerable cooperation with the Navy and Navy oriented activities.

Mr. Vine made two trips totaling about five weeks at Pearl Harbor working with COMSUBPAC, COMASWFORPAC and the Fleet Numerical Weather Facility on oceanographic aspects of pro and anti-submarine warfare in the Pacific and to assist in their oceanographic-acoustic training programs. This was done cooperatively with Mr. Swanson of the U. S. Naval Oceanographic Office who is now stationed at COMSUBPAC. A day of comparable discussions was spent at the Fleet Numerical Weather Facility at Monterey while enroute to Pearl Harbor. An important part of these two visits was to refresh Woods Hole on modern Fleet problems.

Specific activities were:

1) Two lectures and study sessions with submarine sonar operators.
2) A lecture to the submarine Prospective Commanding Officer (PCO) class and to a group of FBM personnel.

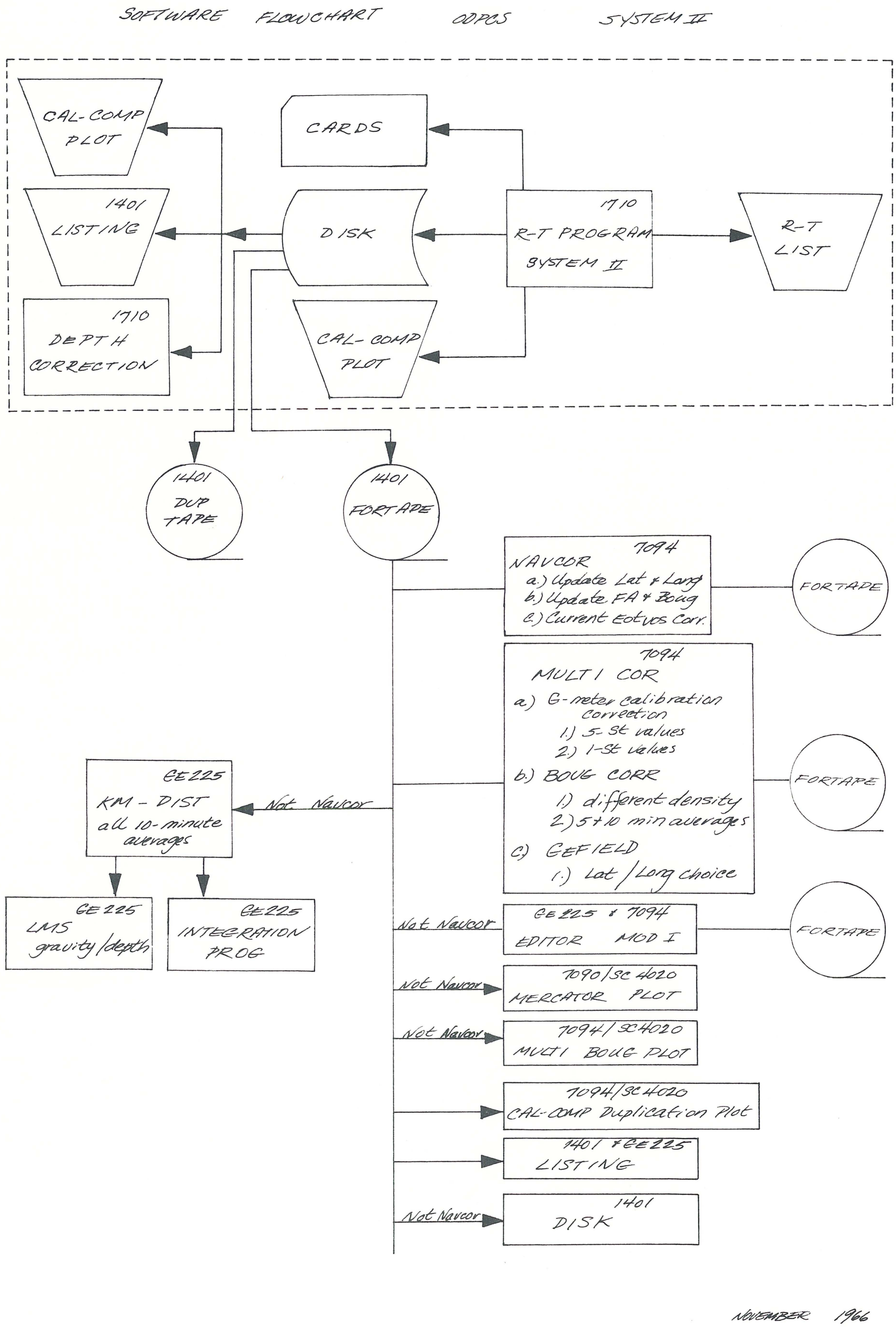

Figure 6. Inter-relation of Real-Time and Post-Cruise Computer Programs.

3) The making of a short TV film on submarine oceanographic-acoustics in the Pacific.
4) Discussions of deep submersible problems with COMSUBPAC staff at Pearl Harbor and at their principal deep submergence activity at San Diego. A stop enroute was made at the Lockheed-Sunnyvale plant to inspect their new deep submersible DEEP QUEST and to discuss oceanographic uses and accessories for the Navy's experiment Deep Rescue Submersible.
5) At San Diego Mr. Vine was brought up to date on the oceanographic-acoustic support work that NEL is doing for Fleet and R& D support.
6) Most of the time was spent discussing their problems with staff, operational, and training people. A simple but special set of instructions for refraction correlations for their sonar was made for BARB.

Several projects and training aids were initiated but are not yet finished:

7) A brief set of oceanographic-acoustic notes for operators, to call their attention to particular effects, areas, or more complete reports.
8) Finding out if special correction curves or instructions are needed for some of the new sonars and if so, to help prepare some.
9) Look into the practicality of updating WHOI Ref. No. 56-50 (C) "Sound Ray Patterns from Shallow Sources in Deep Water" by J. B. Hersey and P. K. Davis for a catalog type book of refraction ray diagrams prepared for training and operational use. Tentative planning and pricing for such a manual is being investigated.

Mr. Stanbrough and Mr. Vine spent August, and Dr. Hays spent several days with a U. S. N. - N. R. C. Study Group at Woods Hole on specialized Navy problems. The report of the study is covered in a recently published classified NRC-Undersea Warfare report. Dr. Hersey, Dr. Hays and Mr. Vine each spent several days a month working with Navy committees and on specific Navy oriented problems.

Mr. Stanbrough and Mr. Bruce attended the one week Navy ASW Tactical School at Norfolk to better acquaint themselves with Navy operating and equipment problems and to see how recent advances in oceanography might best help the fleet.

JOIDES, Committee Meetings (Dr. Von Herzen and Dr. Berggren).

Drs. Von Herzen and Berggren of our staff are members of the JOIDES Atlantic Advisory Panel. Meetings on 30 September 1966 were attended. Dr. Von Herzen is serving as secretary of this panel.

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APPENIDX

Personnel

SENIOR SCIENTISTS

Backus, Richard H.
Hays, Earl E., Dept. Chairman (Since May)
Hersey, J. B. - Department Chairman
Vine, Allyn C.

ASSOCIATE IN OCEANOGRAPHY

Schevill, William E.

ASSOCIATE SCIENTISTS

Beckerle, John C.
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Bunce, Elizabeth T.
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Von Herzen, Richard P.

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Dow, Willard, Electronics Engineer
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Berggren, William A.
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